

## SECTION 34 11 32

### RESILIENT TIES

#### PART 1 –GENERAL

##### 1.01 SECTION INCLUDES

- A. Standard Resilient Ties (RT).
- B. Special Trackwork Resilient Ties (SPRT).

##### 1.02 MEASUREMENT AND PAYMENT

- A. Measurement and payment will be made for the item in the Bid Schedule of the Bid Form. All costs in connection with the work specified herein will be considered to be included.

##### 1.03 REFERENCES

- A. American Railway Engineering and Maintenance of Way Association (AREMA):
  - 1. AREMA Manual
  - 2. Manual for Railway Engineering
- B. American Society for Testing and Materials (ASTM):
  - 1. ASTM C39/C39M      Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens
  - 2. ASTM C78/C78M      Standard Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)
  - 3. ASTM C192/C192M    Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory
  - 4. ASTM D412            Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers-Tension
  - 5. ASTM D573            Standard Test Method for Rubber-Deterioration in an Air Oven
  - 6. ASTM D1149           Standard Test Methods for Rubber Deterioration-Cracking in an Ozone Controlled Environment
  - 7. ASTM D2240           Standard Test Method for Rubber Property-Durometer Hardness
  - 8. ASTM A615/  
A615M                    Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement

- C. Precast/Prestressed Concrete Institute (PCI):
  - 1. PCI MNL 116                      Manual for Quality Control for Plants and Production of Precast and Prestressed Concrete Products

#### **1.04 SUBMITTALS**

- A. Provide additional Submittals as required herein.

#### **1.05 RT AND SPRT SUBMITTAL**

- A. A RT and SPRT shall consist of independent precast concrete blocks, suitably reinforced and incorporate two rail fastening shoulders and SPRT baseplate anchoring. The proposed RT and SPRT system shall permit individual lateral adjustment of each rail, along with the third rail, using replaceable shims.
- B. Separate Submittals are required for RTs and SPRTs.
- C. Submit detailed Shop Drawings indicating the following:
  - 1. Dimensional details of RTs and SPRTs showing plan, elevation, and cross sections. Include concrete strength and material specifications.
  - 2. Location and spacing of reinforcement.
  - 3. Dimensions and tolerances and location of rail fastening components for rail and rail joints, and turnout plates.
  - 4. Plans and samples to demonstrate conformance with the track tolerance requirements.
  - 5. Submit three samples to the District's Representative within 90 Days following award of the Contract, of complete all various rail fasteners, including embedded shoulders, spring clips, insulators, and tie pads for review by the District's Representative.
  - 6. Recommendation for handling, transporting, and stacking of ties.
  - 7. Submit list of sources proposed by the Supplier to obtain materials requiring approval, certifications, or testing.

#### **1.06 RT AND SPRT QUALITY ASSURANCE AND CONTROL**

- A. Submittals:
  - 1. RT and SPRT assembly drawings.
  - 2. Detailed Shop Drawings and Contract Specifications for all RT and SPRT components.

3. Material certificates demonstrating that the RT and SPRT block pads are made of natural rubber or an equivalent material approved by the District's Representative and permitting to fulfill all the requirements herein.
4. Evidence satisfactory to the District's Representative that the block pad design will guarantee that the performance of the proposed RT and SPRT system will not be negatively affected by the unavoidable ingress of water into the rubber boots during revenue service.
5. Material certificates demonstrating that the RT and SPRT rubber boots are made of SBR and that the SBR content is at least 50 percent.
6. Evidence satisfactory to the District's Representative that the internal rubber boot wall design will be such that a 0.02 inch gap between the rubber boot and the concrete block is maintained during construction, thereby allowing the concrete block to freely move downward as the block pad deflects under load during revenue service.
7. Evidence satisfactory to the District's Representative that the rubber boot wall design will be such that replacing the original rubber boots with maintenance rubber boots having thinner walls will permit a Resilient Tie block pair (both running rail) to achieve the specified one inch lateral adjustment of the RT and SPRT units without compromising the long term performance of the system.
8. Calculations of the concrete block strength, track modulus and maximum pressure per area exerted by the RT and SPRT units against the encasement concrete, both vertically and laterally, and a justification that the resulting values are compatible with the axle load, train speed and track curvature conditions prevailing on the project.
9. A description of how the proposed RT and SPRT system will be installed and permit to achieve the performance criteria and dimensional tolerances specified for the completed track in terms of track gauge, rail cant, horizontal and vertical track alignment, superelevation in curves and future vertical and lateral track adjustment.
10. Production testing plan in accordance with the requirements herein.
11. Quality assurance plan.

B. Qualification Testing

1. All design qualification testing on the cross tie and fastener assembly shall be performed by an approved independent laboratory that is staffed, equipped, and experienced to perform the specified tests.
2. All daily production quality control testing shall be performed in accordance with the approved Test Program Plan.

3. The Supplier shall supply a minimum of 16 independent RT and SPRT units to be tested. These RT and SPRT units shall be Manufactured in the same manner as the Supplier plans to use for production runs. From the lot of 16 RT and SPRT units so produced the District's Representative shall select five units at random to be subjected to qualification testing. If any RT and SPRT unit fails to meet any of the testing requirements assigned to it, another unit shall be selected from the lot by the District's Representative and the corresponding tests shall be repeated. A second failure shall require the production of a new lot of 16 RT and SPRT units and the performance of another complete series of qualification tests.
4. The RT and SPRT units selected for testing shall be permanently marked with identifying numbers in accordance with the following sequence: A1, B1, C1, D1 and E1 for first iteration of tests and A2, B2, C2, D2 and E2 for second iteration of tests.
5. The testing sequence shall be as presented in the qualification test matrix shown in 2.
6. A RT and SPRT unit, fully assembled but not embedded in concrete, shall be aged in an air oven for a period of 70 hours at a temperature of 212 degrees Fahrenheit (or for a period of 336 hours at 160 degrees Fahrenheit if it comprises one or more natural rubber components) in accordance with ASTM D573, Accelerated Aging of Vulcanized Rubber by the Oven Method. EVA rail pads shall be exempt from this test.
7. Before assembly, the metal parts and elastomers shall be hand cleaned and wiped dry. They shall be assembled as shown in the approved shop drawings and installation description. The test configuration shall simulate fully installed embedded RT and SPRT unit conditions, except where specifically stated, and shall consist of two RT and SPRT units on 30 inch centers with a piece of the same rail as specified for the project that is at least 42 inches long assembled to the RT and SPRT units. The minimum encasement concrete depth below the embedded RT and SPRT units shall be two inches. The perimeter of the encasement concrete shall be located at least 20 inches horizontally from the nearest point of an embedded RT and SPRT unit. Any forms shall be removed prior to testing. The embedment concrete shall attain its full compressive strength prior to initiation of testing. The embedment concrete shall have a compressive strength of no less than 4,000 psi in accordance with ASTM C39/C39M.
8. Figure 4 illustrates a typical test assembly.
9. Vertical Assembly Stiffness
  - a. Prior to the test, a minimum of ten 24,000 pound vertical loading cycles shall be applied downward at the center of the rail head midway between the RT and SPRT units to ensure the proper seating of all components. The vertical position of the rail head after the seating procedure shall be used as reference for all measurements taken during the test. A vertical load increasing in increments of 2,000 pounds to a maximum of 24,000 pounds at a rate of no less than 100 pounds per minute and no more than 1,000 pounds per minute shall be applied downward at the center of the rail head midway

between RT and SPRT units. For each increment of load, the vertical deflection of the rail head at each RT and SPRT unit shall be measured to the nearest 0.001 inch and shall be recorded. The load shall be removed and the final position of the rail head shall be measured and recorded. The values for vertical loads versus deflection shall be plotted on a graph.

- b. The average spring rate of the RT and SPRT units shall be between 85,000 pounds per inch and 175,000 pounds per inch for the deflections at single rail seat loads of 4,000 pounds and 12,000 pounds. One minute after the removal of the maximum load, the rail head shall return to within 0.05 inch of the reference position. The RT and SPRT components shall not exhibit evidence of failure such as slippage, yielding or fracture.

#### 10. Lateral Load Test

- a. Prior to the test, a minimum of ten 14,000 pounds vertical loading cycles shall be applied downward at the center of the rail head midway between the RT and SPRT units to ensure the proper seating of all components. The position of the rail head after the seating procedure shall be used as reference for all measurements taken during the test. A vertical load of 14,000 pounds shall then be applied downward at the center of the rail head midway between the RT and SPRT units. A lateral load, increasing in increments of 1,000 pounds to a maximum load of 6,000 pounds, at a rate of no less than 100 pounds per minute and no more than 1,000 pounds per minute, shall be applied horizontally to the rail head at a point 0.625 inches below the top of the rail midway between RT and SPRT units in a direction normal to the vertical load. The lateral displacement of the rail head shall be continuously measured throughout the loading sequence at a point 0.625 inches below the top of the rail at each RT and SPRT unit. The vertical and lateral loads shall be removed and the final position of the rail head shall be measured at each rail seat and recorded. The recorded values for lateral loads versus displacement shall be plotted on a graph.
- b. The lateral displacement of the rail head when fully loaded shall not exceed 0.250 inches from the original gauge line. The difference between the original and final positions of the rail head shall not exceed 0.062 inches. At no time during the test shall a RT and SPRT component exhibit evidence of failure such as slippage, yielding or fracture.

#### 11. Lateral Restraint Test

- a. A static vertical load of 5,000 pounds shall be applied to the rail head midway between the RT and SPRT units. A lateral load shall then be applied at the base of the rail normal to the vertical load midway between the RT and SPRT units increasing in increments of 500 pounds from zero to 14,000 pounds at a rate of no less than 100 pounds per minute and no more than 500 pounds per minute. The lateral displacement of the rail head and rail base at each RT and SPRT unit shall be measured to the nearest 0.001 inch and shall be recorded after each increment of loading.

- b. The lateral displacement of the rail head when fully loaded shall not exceed 0.125 inch from the original gauge line and the lateral displacement of the rail base shall not exceed 0.010 inch from the original gauge line. At no time during the test shall a component exhibit evidence of failure such as slippage, yielding or fracture.
- c. Lateral boot stiffness. Repeat procedure 11.a, above, except
  - 1) Measuring block lateral displacement to the adjacent support concrete.
  - 2) Without a vertical load and
  - 3) Limiting the maximum lateral rail base load to that of initial rail base uplift or 14,000 pounds, whichever is lower, then reduce the load incrementally while measuring the lateral block deflection at each increment.
  - 4) Submit the recorded load and deflection data. The submittal approval will be on procedural compliance with load range, data (reasonably uniform curve) and accuracy. There is no pass/fail requirement.

## 12. Longitudinal Restraint Test

- a. A load shall be applied longitudinally to the rail at its base increasing in increments of 500 pounds at a rate of no less than 100 pounds per minute and no more than 500 pounds per minute. Load increments shall be maintained constant for at least one minute before increasing the load to the next increment. The load shall be increased in these increments until slippage occurs between the RT and SPRT units and the rail. The longitudinal displacement of the rail shall be measured relative to the RT and SPRT unit nearest the load application point and recorded continuously to the nearest 0.001 inch from the time of initial loading, through rail slippage, to the time of rail unloading. The values for longitudinal load versus displacement shall be plotted on a graph.
- b. The longitudinal load at slippage shall be equal to or greater than 5,000 pounds. At no time during the test shall a RT and SPRT component exhibit evidence of failure such as slippage, yielding or fracture except for the slippage between the rail fastenings and the rail.

## 13. Vertical and Lateral Repeated Load Test

- a. A vertical load shall be applied to the rail head midway between RT and SPRT units to produce a vertical downward load of 40,000 pounds. A lateral load shall be applied to the gauge side of the rail head midway between RT and SPRT units to produce a load normal to the vertical load of 16,000 pounds. A second lateral load shall be applied to the field side of the rail head midway between RT and SPRT units to produce a load normal to the vertical load of 16,000 pounds. The lateral loads shall be applied 0.625 inch below the top of the rail. 100,000 cycles of vertical and field side lateral loading shall be applied first. Then 80,000 vertical load shall be applied with the 16,000 pound gage side lateral loading for 100,000 cycles. The load cycle frequency

shall be regulated to prevent the temperature of the components from exceeding 160 degrees Fahrenheit.

- b. The RT and SPRT units shall withstand 100,000 cycles of load application in each direction with no evidence of failure. Upon visual inspection, no component of the RT and SPRT units shall exhibit evidence of failure such as slippage, yielding, abrasion, or fracture during the test. Unacceptable elastomer degradation is defined as the inability of the RT and SPRT unit to meet the post fatigue tests outlined in the qualification test matrix, 2. Adjusting or tightening of components shall not be permitted at any time during the test.

#### 14. Voltage Withstand Test

- a. The concrete slab shall be grounded. A direct current potential of 15 kV (or as high as achievable with the testing equipment if built-in safety features do not permit to reach 15 kV) shall then be applied to the rail head for one minute.
- b. The elastomers shall withstand this test with no visible damage such as splits, cracks, pinholes or fracture.

#### 15. Electrical Resistance and Impedance Tests

- a. The concrete slab shall be grounded. A current potential of 750 volts DC shall be applied to the rail head for three minutes. The resistance shall be measured with an accuracy of plus or minus two percent.
- b. The rail pad and insulators shall be removed from the assembled test configuration and immersed in distilled water for 70 hours at 95 degrees Fahrenheit. After removal from the water immersion, without drying, and with no portion of the soaked materials or RT and SPRT units at a temperature below 95 degrees Fahrenheit, the soaked materials shall be reinstalled. With the concrete slab grounded, 750 volts DC shall be applied to the rail head for three minutes. A potential of 50 volts AC shall then be applied to the rail head for three minutes for each increment of measurement for frequencies from 20 Hz to 10 kHz, in increments of 20 Hz up to 100 Hz, 200 Hz up to 1,000 Hz, and 2,000 Hz up to 10 kHz. The calculated impedance shall be based on plus or minus two percent accuracy and recorded for each frequency increment.
- c. The minimum resistance for 750 volts DC shall be ten megohms when dry and 1 megohm when wet. The minimum impedance for any frequency between 20 Hz and 10 kHz with 50 volts AC shall be 10,000 ohms.

#### 16. Rail Fastening Uplift Test

- a. The configuration for the rail fastening uplift test is a single RT and SPRT unit rigidly restrained from uplift displacement with a rail section fully fastened to the RT and SPRT unit in accordance with the Supplier's installation instructions. The rail fastenings from the second RT and SPRT unit shall be removed. The load application point on the rail shall be centered between the installed rail fastenings in a manner that will produce uniform loading to each fastening. An uplift load of 2,000 pounds plus the weight of the rail used in the test assembly shall be applied to the rail perpendicular to the rail seat. The

displacement of the rail relative to the RT and SPRT unit shall be measured continuously from initiation of loading through maximum loading to the full release of loading. Without resetting (i.e. without re-zeroing) the deflection measurement, the uplift load and release shall be repeated five times.

- b. The position of all components after release of load shall be within the tolerances stated on the shop drawings. The rail fastening components shall not permanently deform. The difference in uplift displacement at 2,000 pounds between any one of the five repetitions of loading and the average total displacement of all repetitions shall not be greater than + five percent of the average total displacement. At no time during the test shall any RT and SPRT component exhibit evidence of failure such as slippage, yielding or fracture.

#### 17. Tests Performed on Individual RT and SPRT Components

##### a. Reinforced Concrete Blocks

- 1) The Supplier shall produce eight test cylinders from a single pour of concrete used in the manufacture of the concrete blocks. The vibration of the casting machine or a vibrating table shall be used to compact the concrete in the molds. The molds shall be moist cured from the time of molding until the moment of test. The curing of the concrete cylinders shall be performed in accordance with ASTM C192/C192M or other equivalent specification. Four test cylinders shall be tested at seven days, two for compressive strength and two for flexural strength. If applicable four test cylinders shall be tested at or beyond 28 days, two for compressive strength and two for flexural strength. The flexural strength test shall be executed in accordance with ASTM C78/C78M (beams) or other equivalent specification.
- 2) Compressive strength,  $F_c = 7000$  psi
- 3) Flexural strength,  $F_t = 700$  psi

#### 18. Concrete block tests

- a. The Supplier shall submit three concrete blocks of each type to the tests specified below.
- b. The dimensional tolerances shall conform to the approved shop drawings when measured with instruments or go/no go gauges as stipulated in the approved Contract Specifications.
- c. The concrete block shall be visually inspected for cracks, structural defects and surface finish.
- d. The concrete block shall not present cracks, structural defects, or surface finish defects incompatible with the satisfactory long term performance of the system.

#### 19. Rail Fastening Tests shall not be performed before 28 days or a 7000 psi concrete compressive strength is achieved, whichever is sooner. The rail fastenings shall be subjected to the pull-out and torque tests described in Article 1.8 of this Section.



## 20. Positive Bending Moment Test

- a. This test shall not be performed before 28 days or a 7,000 psi concrete compressive strength is achieved, whichever is sooner.
- b. The configuration for the positive bending moment test shall be as shown in Figure 5.
- c. The objective of this test shall be to record the load required to produce the first crack in the concrete block, and to evaluate the reinforcements' effectiveness in closing the cracks after the removal of the load.
- d. Levels P1 and P2.
  - 1) The concrete block shall be positioned under the press actuator and subjected to an initial load of 20,000 pounds.
  - 2) The loading of the concrete block shall be progressively increased by 4,000 pounds increments. After each increment, the load shall be maintained for a minimum of one minute while both side surfaces of the concrete block are examined for the presence of cracks.
  - 3) P1 shall be defined as the load required generating the first crack.
  - 4) After P1 has been reached, the concrete block shall be subjected to successive zero-to-peak loading cycles. The peak load of each cycle shall be increased by a 4,000 pounds increment.
  - 5) In each cycle, the load shall be gradually increased from zero up to the peak load. The peak load shall be held for a minimum of one minute before being fully released.
  - 6) Once the load has been released, the width of the cracks on the side surfaces of the unloaded concrete block shall be measured and recorded.
  - 7) The crack widths shall be measured at the level corresponding to the theoretical position of the lower reinforcement's centroid. If it is not possible to measure a crack at this level due to chipping of the concrete or surface imperfections, measurements shall be taken equidistant and as close as possible above and below this level; the two values shall be averaged to obtain the width of the crack.
  - 8) P2 shall be defined as the peak load of the last cycle in which the widest crack on the concrete block is closed after the removal of the load. A crack whose width does not exceed 0.002 inch shall be considered to be closed.
- e. Levels P3 and P4.
  - 1) After reaching level P2, the incremental loading cycles shall be resumed.
  - 2) P3 shall be defined as the peak load of the last cycle in which the opening of the widest crack on the unloaded concrete block is not greater than 0.02 inch.

- 3) After reaching level P3, the load shall be gradually increased until the ultimate failure of the rail concrete block.
- 4) P4 shall be defined as the maximum load carried by the concrete block.

f. Specified values for P2 and P3 are: P2<sup>3</sup> 40,000 pounds, P3<sup>3</sup> 60,000 pounds.

#### 21. Block Pads

- a. The Supplier shall supply nine block pads of each type for qualification testing. All nine block pads shall be subjected to the aspect, flatness and dimensional controls. Five block pads out of the aforementioned nine shall then be subjected to the static spring rate test followed by the static versus dynamic spring rate qualification test for two of them, the high and low temperature spring rate qualification test for one of them, the before versus after heat aging spring rate qualification test for another one and the before versus after fatigue spring rate qualification test for the last one.
- b. The porosity test shall be performed on two of the remaining four block pads as well as on the block pad subjected to the fatigue spring rate qualification test, both before and after the completion of the fatigue test.
- c. The last two block pads shall be subjected to the dynamic stiffness test.

22. The test block pad shall be visually inspected and found flawless and clean edged. Small surface defects, such as chips or blisters, shall, however, not constitute cause for rejection.

#### 23. Flatness Control

- a. A full block pad shall rest on a flat, level and smooth control surface. A straight, rigid rule shall be laid across the top surface of the pad along its length. The rule shall rest across the pad without compressing it.
- b. The flatness shall be controlled at a minimum of three locations: one inch from each edge and at the centerline of the pad. The procedure shall be repeated with the rule placed along the width of the pad. If visible deformations exist in other locations, these locations shall be verified as well in accordance with the same procedure.
- c. No gap or pocket between the rule and the top surface of the pad shall exceed 0.02 inch in depth or 0.80 inch in length.
- d. The vertical distance measured from the bottom edge of the rule on either side of the pad (lengthwise and widthwise) and the control surface shall be in accordance with the thickness dimension and tolerance specified in the approved drawing of the block pad.

24. The dimensional tolerances shall be in accordance with the approved drawing of the pad.

## 25. Static Deflection Measurement, block support pad(s)

- a. This test shall be performed at room temperature (68 degrees Fahrenheit) on a complete block pad. For systems with multiple elastomeric members supporting the concrete block, this test shall be performed on each elastomeric member separately. Elastomeric members such as boots that require alteration for blocks to fully rest on the member shall be altered for test purposes to permit full block bottom extents to rest completely on the bottom portion of the elastomeric member.
- b. The loads shall be transmitted to the block pad through the block designed for each pad. Prior to the application of a load, the respective block shall rest with all its weight on the pad.
- c. Gauges, positioned at the corners of the loading block, shall be used to measure the deflection of the pad.
- d. The block pad shall be subjected to ten preloading cycles between 0 and 12,000 pounds at a rate of at least one cycle per minute but without creating internal pad heat
- e. The deflection gauges shall be set to zero after the deflection measurements have stabilized to within 0.001 inches from preload cycling.
- f. Loading shall be applied in increments of 2000 pounds to 12,000 pounds, measuring time and deflection at each load increment.
- g. Static Stiffness Acceptance Criteria:
  - 1) Spring rate shall be calculated using the deflections at loads of 4,000 pounds and 12,000 pounds. The test report shall have a table of all measured load and deflection data (at each 2,000 pound increment) and the time in milliseconds of each measurement.
  - 2) The static spring rates measured at 120 degrees Fahrenheit and 15 degrees Fahrenheit shall not differ from the static spring rate measured at 68 degrees Fahrenheit by more than 20 percent.
  - 3) The static spring rate measured at 68 degrees Fahrenheit after an artificial heat aging at 160 degrees Fahrenheit during 72 hours shall not differ from the static spring rate measured before the artificial heat aging by more than 30 percent.
  - 4) The static spring rate measured at 68 degrees Fahrenheit after 3 million fatigue loading cycles between near zero and 12,000 lbs. shall not differ from the static spring rate measured before the beginning of the fatigue test by more than 20 percent. The cycling rate shall ensure that overheating of the block pad does not occur.

## 26. Dynamic stiffness (dynamic spring rate)

- a. Configuration. The test shall be conducted using a single block of the configuration in Figure 4. Alternatively, the test may be conducted with a two blocks as in Figure 4 using double the specified loading, reporting the load as one half the actual applied load. In this test, downward loads and deflections are positive.

- b. A full block assembly with all pads and rail fasteners shall be subjected incremental vertical loads of 2,000 pounds to 12,000 pounds, measuring deflections and pausing for one minute at each load increment. The static spring rate shall be calculated using the measured load and deflection at 4,000 pounds and 12,000 pounds. A table of all load, deflection and time of measurement shall be included in the report.
- c. A vertical pre-load of 6,000 pounds shall be applied to the rail head. The deflection measurements shall be zeroed with the pre-load applied.
- d. The block assembly shall then be subjected to cyclical loads between 0 and 12,000 pounds (6,000 pounds cyclic load amplitude). with the corresponding deflection shall be recorded at 0.005 second intervals for cyclic loading of ten Hz progressing in 20 Hz increments to 250 Hz, or the maximum stable test equipment frequency within the load range, whichever is less. A minimum of 20 load cycles shall be performed at each frequency. The first five and last five load cycles of each frequency's loading shall be ignored in computing dynamic stiffness.
- e. The data (load, deflection, time) shall be recorded to a Microsoft Excel spreadsheet, with each cyclic data set saved in different electronic files. The dynamic stiffness shall be reported for each data set and the electronic files submitted on disk with the final test report.
- f. Dynamic Stiffness and Damping Calculation:

$$k = \frac{F_0}{x_0 [1 + \tan^2 \psi]^{1/2}} + m\omega^2$$

$k$  = dynamic stiffness, lb/inch

$x_0$  = deflection peak amplitude, inch; maximum value in the sinusoidal variation with load (see Figure 1).

$m$  = mass of the block and rail assembly, not including supporting base pads under the block.  $m$  = assembly weight/gravity constant = weight in pounds/386.4 inches/sec<sup>2</sup>. Units: lb-sec<sup>2</sup>/in

$F_0$  = amplitude of the cyclic load, pounds = 12,000 – 6,000 = 6,000 pounds

$\omega$  = cyclic frequency (radians/sec). e.g. 10 Hz. cyclic loading is 20 $\pi$  radians/sec = 62.83 radians/sec

$\psi$  = phase shift

$\tan \psi = \frac{\text{Time Delay}}{\text{Period}}$ ; see Figure 1 for Time Delay and Period determination from measured data.

The assembly damping is calculated from  $k$ :

$$c = \frac{(k - m\omega^2)\tan\psi}{\omega}$$

Where  $c$  = Damping coefficient (lb-sec/in)

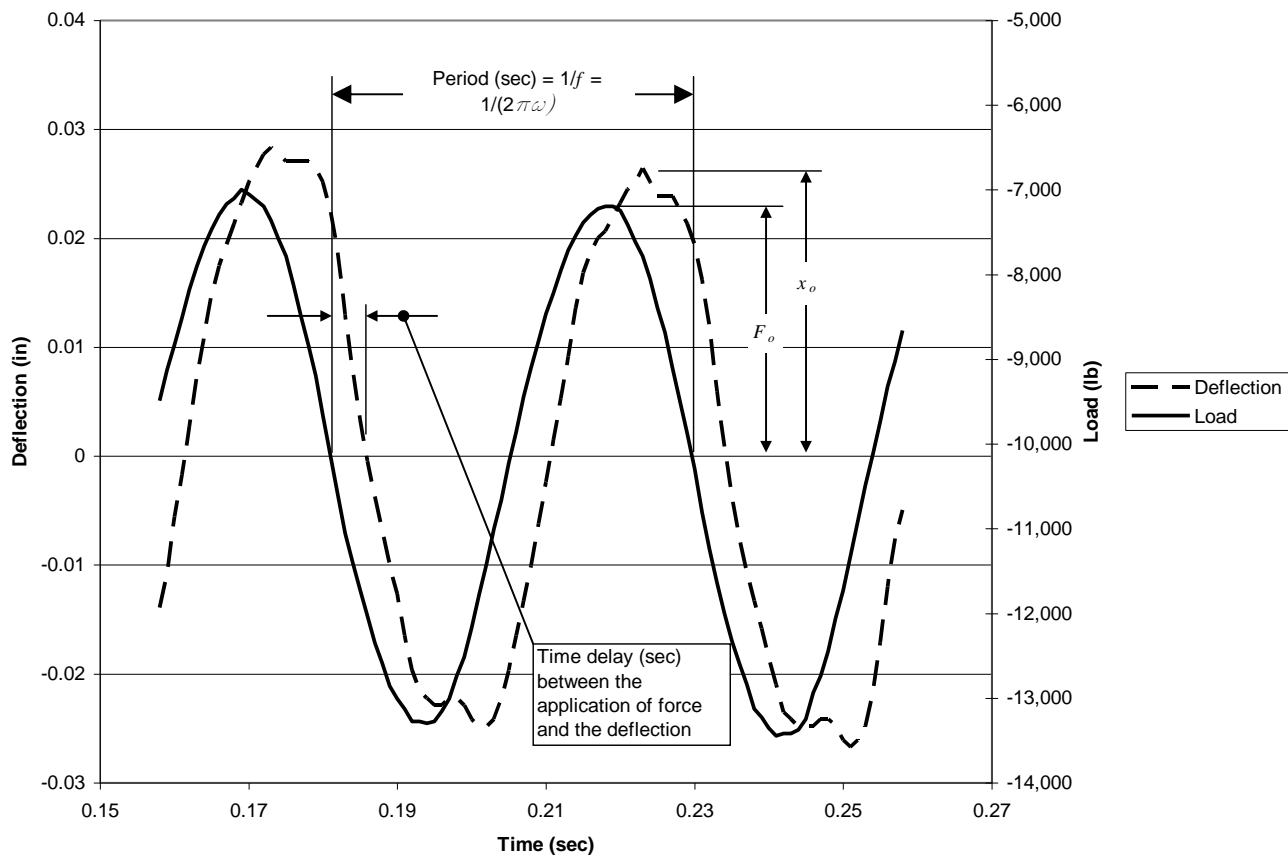


Figure 1 Illustration of Cyclic Load-Deflection Data for Determination of Dynamic Stiffness And Damping.

- g. There is no acceptance criteria for dynamic stiffness or damping values. The acceptance of the submittal will be based on compliance to the procedure, and quality and accuracy of the data.

#### 27. Ozone Test

- a. The block pad material shall be exposed to 25 pphm ozone for 168 hours at 104 degrees Fahrenheit in accordance with ASTM D1149.
- b. No cracks shall be apparent under a magnification of seven after exposure.

#### 28. Porosity Test

- a. This test shall be performed at 68 degrees Fahrenheit.

- b. The initial weight (P0) of the block pads shall be measured and recorded.
- c. The block pad shall be submerged in distilled water and compressed between two flat steel plates until the distance between the steel plates and therefore the thickness of the compressed block pad reaches 2/3 of the initial pad thickness. The block pad shall remain compressed during one minute. The block pad shall then be unloaded and maintained free of load for another minute. This cycle shall be repeated three times before the block pad is removed from the water.
- d. The block pad shall be superficially dried and their weight P1 shall be measured and recorded immediately thereafter.
- e. The difference between P1 and PO shall not exceed 0.07 ounces for any of the block pads tested.

## 29. Rubber Boots

- a. The Supplier shall submit three rubber boots of each type to the tests specified below.
- b. The rubber boot shall be visually inspected and found flawless and clean edged. Small surface defects, such as chips or blisters, shall, however, not constitute cause for rejection.
- c. The dimensional tolerances of the rubber boot shall be in accordance with the approved drawing of the boot.

## 30. Measurement of the Shore A Hardness

- a. The Shore A hardness of the boot material shall be measured according to ASTM D2240, indentation hardness of rubber and plastics by means of a durometer. Measurements shall be made at five points on the upper surface of the boot base.
- b. The average of the measured Shore A values must fall between 70 and 80.

## 31. Measurement of the Ultimate Strength and Elongation at Break

- a. Twelve samples (six longitudinal and six transversal) shall be cut from the base of the boot according to ASTM D412, method A, die C. The thickness of the samples shall correspond to that of the base of the boot.
- b. The ultimate strength and the elongation at break shall be measured on six samples (three longitudinal and three transversal).
- c. The remaining six samples (three longitudinal and three transversal) shall be artificially aged according to ASTM D573 for 72 hours in an oven maintained at a temperature of 212 degrees Fahrenheit + three degrees Fahrenheit. The ultimate tensile strength and the elongation at break shall be measured after cooling the samples at room temperature (+68 degrees Fahrenheit) for not less than 16 hours.

- d. For each set, the median value of the three measures shall be recorded and the values shall meet the following:
  - 1) Minimum tensile strength of the initial section before ageing 1740 psi and 1450 psi after ageing
  - 2) Minimum elongation at break before ageing 250 percent and 180 percent after ageing

#### **1.07 ANCHORAGE ASSEMBLIES QUALIFICATION TESTING (TURNOUT PLATE CONCRETE INSERTS)**

- A. For the acceptance of anchorage design, each anchorage assembly shall satisfy the test requirements and the test results shall not be averaged.
- B. Test Preparation
  - 1. The anchorage inserts or shoulder casting shall be embedded in a reinforced concrete test block. The test block size and configuration shall conform to one of the two test blocks shown in Figure 3. The size and configuration of the test block shall be determined by the Supplier, subject to approval by the District's Representative. The sides shall be vertical and the top and bottom shall be horizontal. The inserts and reinforcing steel shall be positioned as they would be in track. The inserts or shoulder casting shall be vertical, with the top face flush with the concrete surface. The inserts or shoulder castings shall be set in the concrete before or during the concrete placing. Post-drilling and placing of inserts or shoulder castings with resins or grouts shall not be permitted.
  - 2. The concrete test block shall have a compressive strength of 4,000 to 6,000 pounds per square inch as determined by ASTM C39/C39M. The tests on the inserts or shoulder castings shall not begin until the concrete has reached the specified compressive strength.
  - 3. The reinforcing steel shall be placed as shown on Figure 3. Use ASTM A615/A615M, Grade 60 steel.
  - 4. The insert anchor bolts or shoulder casting test attachment shall be appropriately engaged for maximum test loading before load application.
  - 5. The number of test blocks required to perform the anchorage assemblies qualification testing shall be determined by the Supplier, subject to approval by the District's Representative.
- C. Qualification Tests
  - 1. Eight anchorage assemblies identical in design to those specified for supply with the RT and SPRT shall be required to perform the tests specified herein.
  - 2. Two separate anchorage assemblies shall be used for each of the three tests.

D. Restrained Pullout Test

1. Contact rail inserts, switch machine mounting bolt inserts
  - a. Place a 8 inch by 8 inch by 1/2 inch steel plate with a 3 1/2 inch diameter hole in its center, centered over an anchor bolt. Apply for one minute an upward vertical load, starting at 1,000 pounds and increasing to 40,000 pounds, to the anchor bolt with the reaction force bearing against the steel plate. Repeat the test on one other anchor bolt.
  - b. There shall be no evidence of slippage or cracking of concrete or failure of bond between either of the two bolts or inserts, and concrete.
2. Embedded Cast shoulder
  - a. Place a 8 inch by 8 inch by 1/2 inch steel plate with a 3 1/2 inch square hole in its center, centered over an embedded shoulder. Alternative: Propose for Engineer approval a different load reaction plate suitable for the RT or SPRT tie design at a shoulder.
  - b. Apply for one minute an upward vertical load, starting at 1,000 pounds and increasing to 40,000 pounds, to the embedded shoulder through a clevis, bolt or other suitable device through the shoulder's spring clip hole, with the reaction force bearing against the steel plate. Repeat the test on one other embedded cast shoulder.
  - c. There shall be no evidence of slippage or cracking of concrete or failure of bond between either of the embedded shoulders or concrete embedment.

E. Unrestrained Pullout Test

1. Contact rail inserts, switch machine mounting bolt inserts
  - a. Apply a vertical pullout load on an anchor bolt, in such a manner that no restraining load is applied to the concrete within a radius of six inches from the center of the bolt. The load application shall start at 1,000 pounds, be increased until a load of 12,000 pounds occurs, be held at 12,000 pounds for at least one minute and be released. Inspect the test block for evidence of concrete cracking or failure of bond between bolts or inserts, and concrete. Repeat the test on one other anchor bolt.
  - b. After successful completion of the Unrestrained Pullout Test, reapply a vertical pullout load as specified in herein. The load application shall start at 1,000 pounds and be increased until fracture of the concrete test block. Inspect the anchor bolt and anchor insert for evidence of failure.
  - c. There shall be no evidence of concrete cracking or failure of bond between either of the two bolts or inserts, and concrete when tested to a 12,000 pound pullout load.
  - d. There shall be no evidence of insert fracture, or bolt or insert thread stripping when tested to fracture of the concrete test block.



## 2. Embedded Cast shoulder

- a. Apply a vertical pullout load on an embedded shoulder, in such a manner that no restraining load is applied to the concrete within a radius of six inches from the center of the bolt. The load application shall start at 1,000 pounds, be increased until a load of 12,000 pounds occurs, be held at 12,000 pounds for at least one minute and be released. Inspect the test block for evidence of concrete cracking or failure of bond between bolts or inserts, and concrete. Repeat the test on one other embedded shoulder.
- b. After successful completion of the Unrestrained Pullout Test, reapply a vertical pullout load as specified in herein. The load application shall start at 1,000 pounds and be increased until fracture of the concrete test block. Inspect the anchor bolt and anchor insert for evidence of failure.
- c. There shall be no evidence of concrete cracking or failure of bond between either of the embedded shoulders or concrete when tested to a 12,000 pound pullout load.
- d. There shall be no evidence of embedded shoulder fracture when tested to fracture of the concrete test block.

## F. Torsion Test (contact rail mounting inserts and switch machine mounting bolt inserts, only)

1. An anchor bolt shall be subjected to a torque at least 100 percent greater than the design installation torque submitted with the installation requirements specified herein. The load shall be held for three minutes and released. Repeat the test on one other anchor bolt.
2. There shall be no evidence of failure of the bond between either of the two bolts or inserts, and concrete.

## 1.08 PACKAGING, LOADING, SHIPPING, AND HANDLING

- A. The Supplier shall submit a Stockpile Plan to the District's Representative for approval that defines how resilient ties and fastener components will be stacked and the area required.
- B. Resilient ties shall be lifted and supported during manufacture, storage, transportation, loading, unloading, and stockpiling in a way which will prevent chipping, spalling, cracking, or other damage.
- C. When resilient ties are stacked in multiple tiers, each tier shall be separated with dunnage having sufficient thickness to clear fastening shoulder inserts.
- D. Resilient ties shall be uniformly vertically supported. All dunnage and separators shall in or align with the rail seat area.
- E. Resilient ties sets required for special trackwork units shall be packaged separately and each shall be marked with the special trackwork unit identification number, unique color coding and location number. Complete resilient ties sets shall be first

sent to the manufacturing facility of the special trackwork, for required complete preassembly prior to shipment to the District.

## **PART 2 – PRODUCTS**

### **2.01 DISTRICT-FURNISHED MATERIALS**

- A. There is no DFM.

### **2.02 SUPPLIER-FURNISHED MATERIALS**

- A. All products, tools, materials, equipment and labor required to complete all aspects of the work shall be furnished by the Supplier.

### **2.03 RESILIENT TIES**

- A. RTs and SPRTs shall be steel reinforced concrete fabricated in accordance with domestic industry practice.
- B. RTs shall include concrete blocks with insulated rail fastenings consisting of embedded cast iron shoulders, drive on spring clips, plastic insulators and tie pads.
- C. RTs for contact rail mounting shall also include threaded fastener inserts for 5/8 inch contact rail mounting bolts.
- D. SPRTs for supporting Switch Machines shall also include threaded.
- E. RT and SPRT Rail fasteners shall be BART DMP fasteners: Pandrol e2055 rail clip, Pandrol 3456/2 insulator, Pandrol 6902 tie pad and Pandrol 6575 embedded cast iron shoulder.
- F. RT and SPRT design shall have the following characteristics:
  - 1. Concrete block shall be surrounded on sides and bottom by a single piece molded rubber boot with conforming shapes.
  - 2. Concrete block design shall be eight inch maximum depth from rail seat to bottom of tie.
  - 3. Concrete block design shall hold gage, restraining vertical, lateral and longitudinal BART loads from unreinforced support concrete for a minimum of the bottom 2/3's the tie block depth.
  - 4. Concrete block and rubber boot sides shall be positively tapered to permit vertical removal/replacement without removing any bonding, concrete or fastening other than rail fastenings.
  - 5. Concrete block, pads and rubber boot shall maintain their designed relationship under all service conditions without mechanical fastening or bonding.

6. The system shall have the capacity for lateral adjustment of one inch in either direction in adjustment increments of 1/4 inch.
- G. SPRTs shall include insulated rail fastenings consisting of embedded cast iron shoulders, drive on spring clips, plastic insulators and pads. Threaded fastener inserts shall be provided for attachment of the switch machine and, when required by Contract Drawings, contact rail mounting.
1. Gage plates shall not be used.
  2. Location and tolerances of turnout plates and inserts shall be in accordance with the manufacturer's drawings and specifications and shall yield the tolerances provided herein.
  3. Threaded fastener inserts for switch machines shall be provided shall be the same type required for use for anchor bolts on direct fixation fasteners.
  4. Resilient Ties supporting switch machines shall be one piece between the nearest running rail and the switch machine.

#### **2.04 GENERAL PRODUCTION**

- A. Manufacture all resilient ties using the same methods used to produce qualification test pieces.
- B. Fabrication of the block ties shall conform with applicable requirements of the AREMA Manual, PCI MNL 116, and applicable requirements of Chapter 30, Concrete Ties according to Manual for Railway Engineering.
- C. Production of resilient ties or components prior to the District's Representative's review and approval is prohibited.

#### **2.05 TWO-BLOCK TIE CONCRETE PRODUCTION**

- A. Concrete Quality:
  1. Water content shall be kept to a minimum consistent with the strength requirements and placement needs. Concrete mixes shall be proportioned to produce a compressive strength of at least 7,000 psi when tested at 28 Days in accordance with ASTM C39/C39M.
  2. The 28 Day flexural strength shall be at least 700 psi.
- B. Concrete Mix Proportions:
  1. Unless previous data are available to show that a concrete mix will be satisfactory for the production of concrete block ties, concrete mix designs shall be established by tests on trial batches to achieve the specified strengths. Mix designs shall be submitted to the District's Representative for review and approval.

2. The cement content shall not be less than 660 pounds per cubic yard.
3. Water-cement ratio shall not exceed 0.40 by weight and shall be calculated on the basis of the weight of cement.
4. Trial mixes using aggregate, water, cement, and admixtures proposed for the manufacture of concrete ties shall be made using at least three different water-cement ratios which will produce a range of strengths encompassing those specified herein. For each water-cement ratio, at least three specimens for each age to be tested shall be made, cured, and tested as hereinafter specified.
  - a. Compressive strength tests shall be performed at 28 Days. A curve shall be established showing the relationship between water-cement ratio and compressive strength. The maximum permissible water-cement ratio for the concrete to be used shall be that shown by the curve to produce average strengths of 110 percent of those specified herein, provided the water-cement ratio shall be no greater than 0.40 when measured by weight.
  - b. Flexural strength tests shall be performed at 28 Days as specified in Article herein for each trial mix.
5. The proportions of aggregate to cement shall produce a mixture which will work readily into corners and angles of the forms and around the reinforcement with the assistance of specified vibration, but without permitting the materials to segregate or excess free water to collect on the surface.

## **2.06 RT AND SPRT PRODUCTION TESTING**

- A. Production testing shall be performed at the manufacturer's laboratory or, if such laboratory is not equipped to perform one or more of the tests specified herein, at a qualified outside laboratory.
- B. If all the control and test results specified herein are satisfactory, the daily batch defined as all the concrete blocks of each type produced during one day shall be accepted. Any control or test failure shall cause the daily batch to be rejected.
- C. Perform all production testing as provided herein for qualification testing.
- D. Concrete Control Tests
  1. Produce four test cylinders per production week.
  2. Two test cylinders shall be tested at seven Days, one for compressive strength and one for flexural strength.
  3. Two test cylinders shall be tested at 28 Days, one for compressive strength and one for flexural strength.
- E. Two concrete blocks per daily batch shall be subjected to dimensional control.
- F. Production aspect control shall be performed on all concrete blocks.

G. Fastening Tests

1. Perform pull out test shall be performed on one concrete block per daily batch.
2. Torque test for applicable RTs or SPRTs shall be performed on one concrete block per daily batch.

H. Positive Bending Moment Test

1. Rail seat positive bending moment test shall be performed on one concrete block per daily batch.
2. Every concrete block subjected to this test shall be tested up to level P2.
3. Only every tenth concrete block subjected to this test shall be tested up to level P4.

I. Block Pads

1. Unless otherwise agreed by the District's Representative, batches of block pads shall not exceed 3,000 units of standard plain line block pads and 300 units of all other types of block pads per batch when presented for inspection.
2. Three block pads per batch shall be randomly selected for each production control and test specified herein.
3. If the three control and test results are satisfactory, the batch shall be accepted.
4. If one result does not meet the requirements, the control or test shall be repeated on six additional randomly selected block pads.
5. If more than one of the first three or any of the additional six block pads do not meet the requirements, the batch shall be rejected.
6. The manufacturer shall, however, have the option to subdivide a rejected batch into 500 unit sub-batches and to repeat the controls and tests on each sub-batch using the same acceptance and rejection criteria as above.
7. The following controls and tests shall be performed as indicated herein.
  - a. Aspect Control.
  - b. Flatness Control.
  - c. Dimensional Control.
  - d. Porosity Measurements.

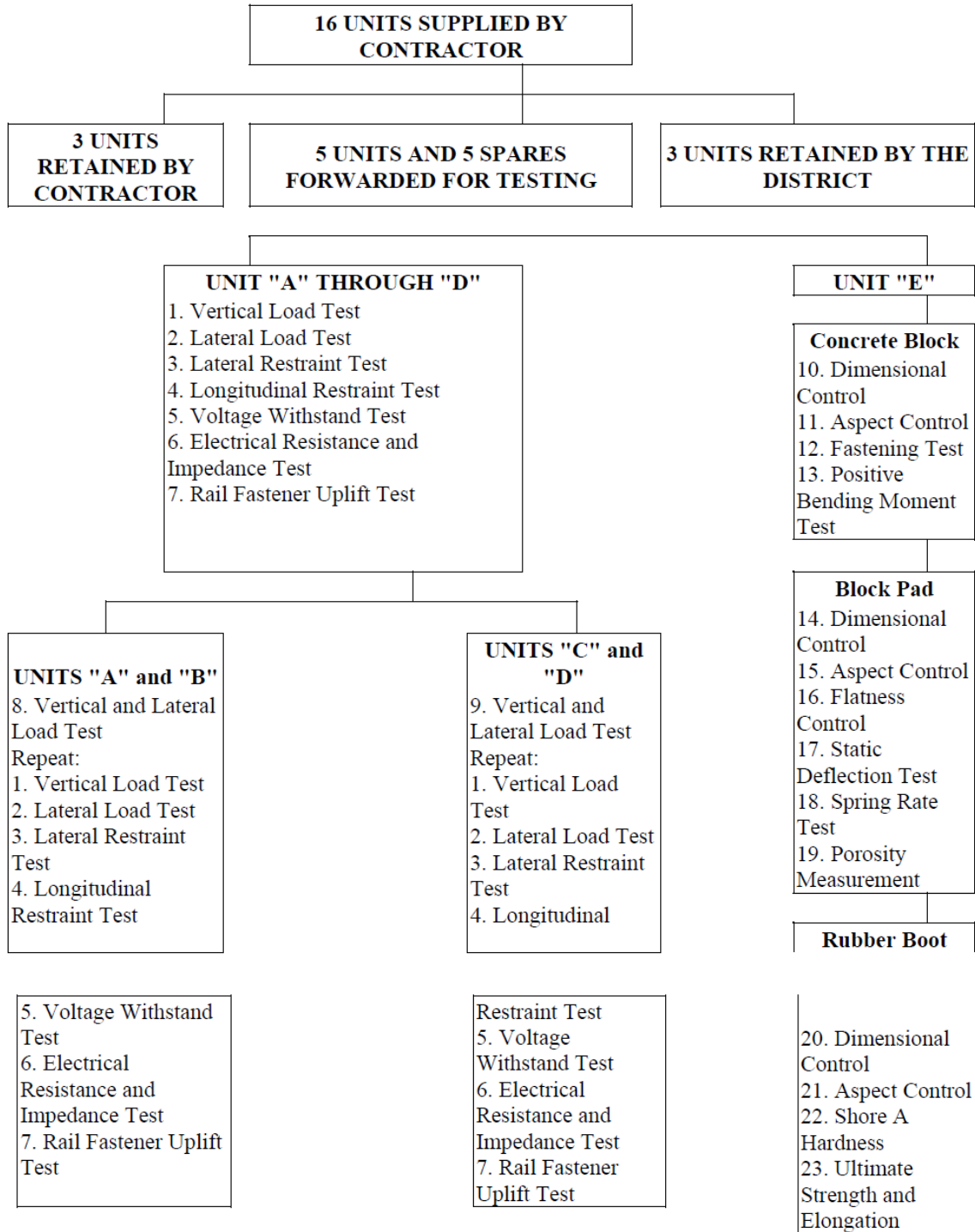
J. Rubber Boots

1. Unless otherwise agreed by the District's Representative, batches of rubber boots shall not exceed 3,000 units of standard plain line rubber boots and 300 units of all other types of rubber boots per batch when presented for inspection.

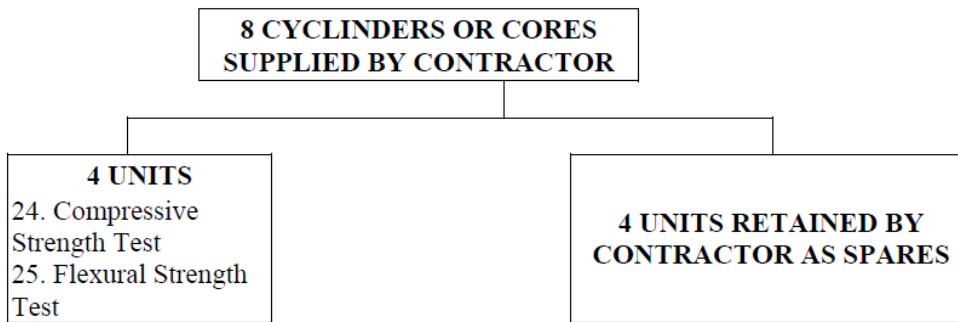
2. Three rubber boots per batch shall be randomly selected for testing.
3. If the three test results are satisfactory, the batch shall be accepted.
4. If one result does not meet the requirements, the test shall be repeated on six additional randomly selected rubber boots.
5. If more than one of the first three or any of the additional six rubber boots do not meet the requirements, the batch shall be rejected.
6. The Manufacturer shall, however, have the option to subdivide a rejected batch into 500 unit sub-batches and to repeat the tests on each sub-batch using the same acceptance and rejection criteria as above.
7. The following controls and tests shall be performed as indicated herein.
  - a. Aspect Control.
  - b. Measurement of the Shore A Hardness.
  - c. Dimensional Control.
  - d. Measurement of the Ultimate Strength and Elongation at Break.

### **PART 3 – EXECUTION**

Not used

**Figure 2 – RT AND SPRT QUALIFICATION TESTING SEQUENCE****PART A – RT AND SPRT UNITS**

**PART B - CONCRETE CYCLINDERS OR CORE**





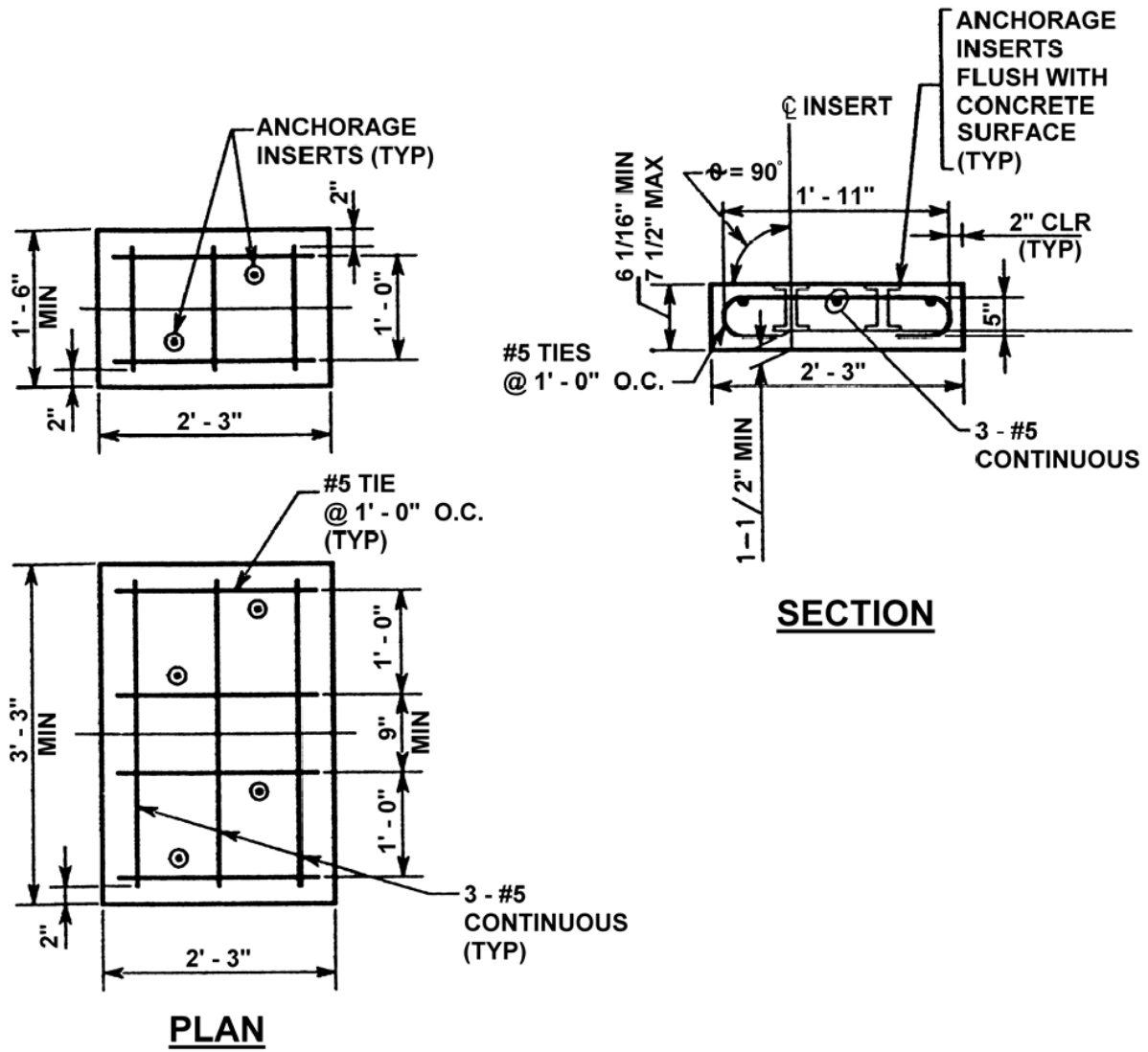


Figure 3. – CONCRETE TEST BLOCK FOR ANCHOR INSERT TEST

# RESILIENT TIES

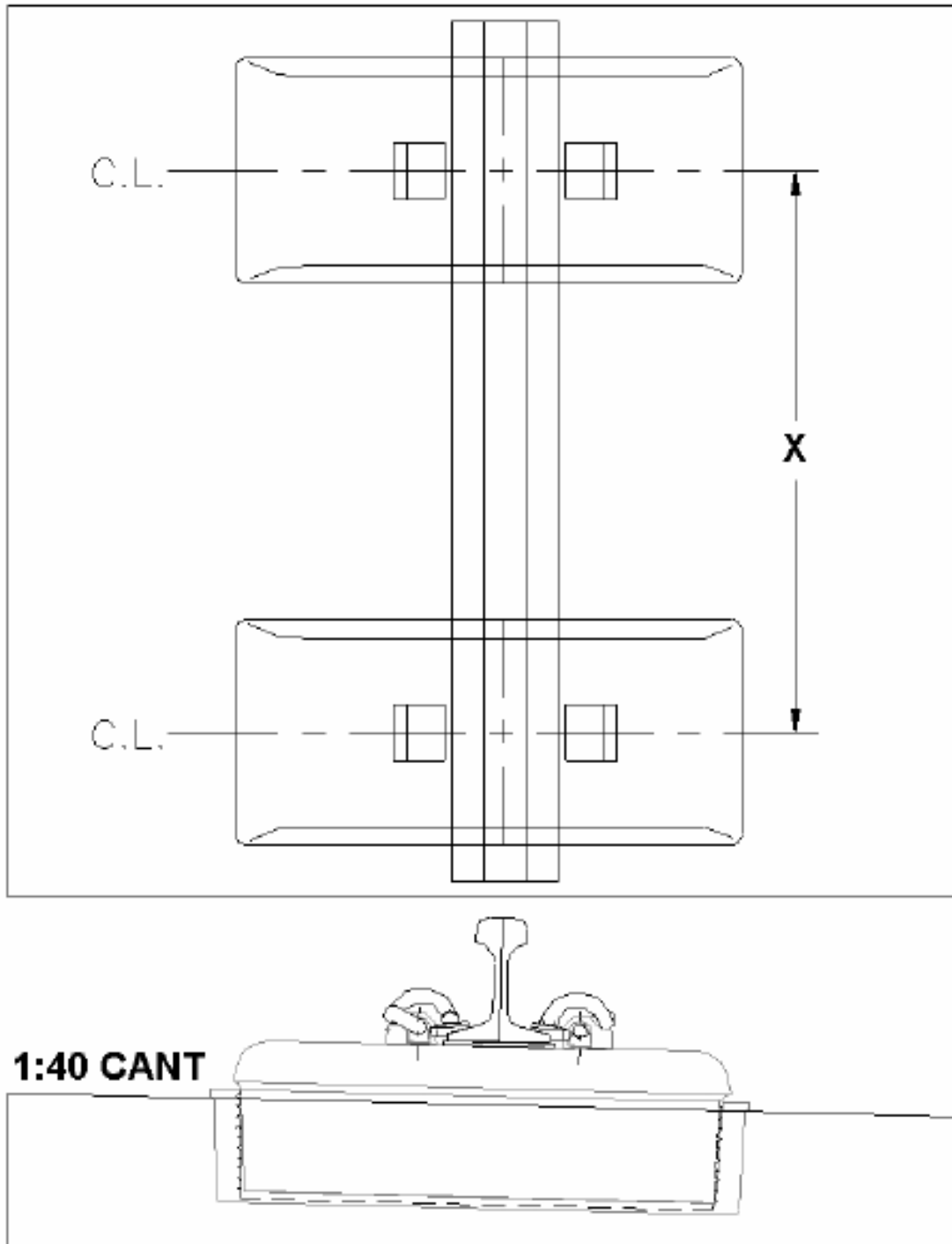


Figure 4 – RESILIENT TIE TEST ASSEMBLY

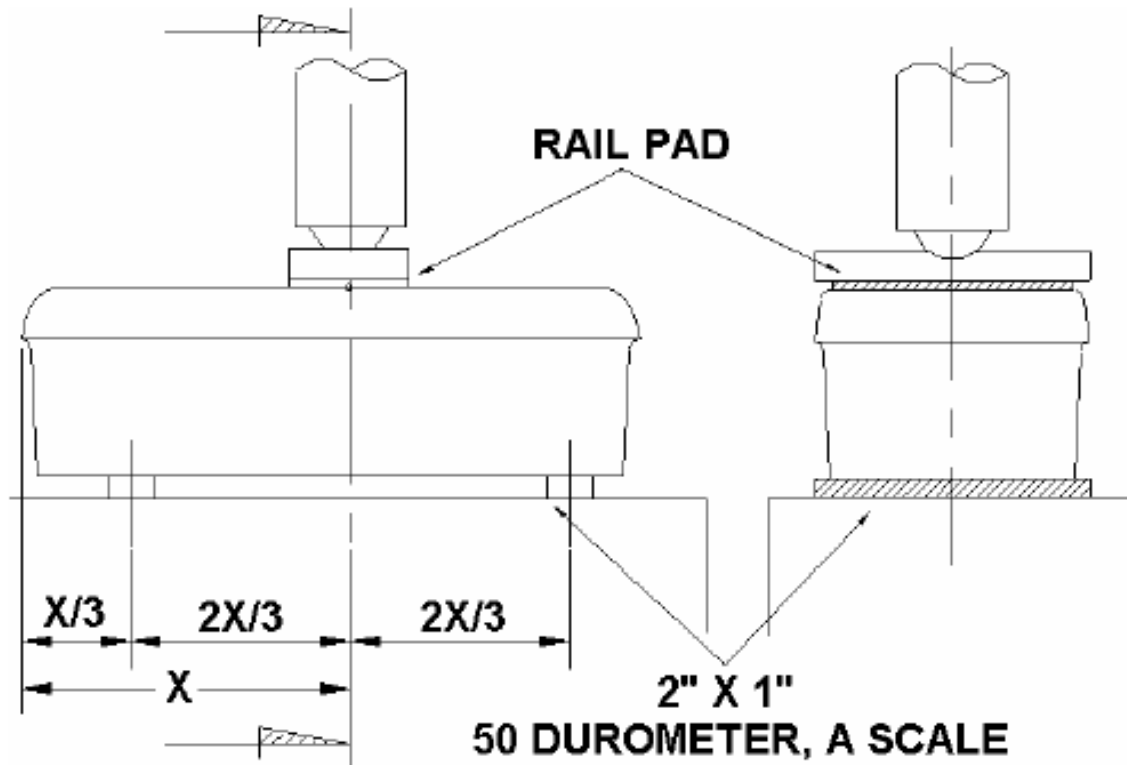


Figure 5 – RESILIENT TIE POSITIVE BENDING MOMENT TEST

END OF SECTION 34 11 32